



U.S. Department of Energy
Energy Efficiency and Renewable Energy

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Investigation of Pressurized Entrained-Flow Kraft Black Liquor Gasification in an Industrially Relevant Environment

**DOE OBP Thermochemical Platform Review Meeting
June 7-8, 2005**

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- **Project Background**
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- **Competitive Advantage**
- **Project Overview**
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- **Plan/Schedule**
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- **Summary**

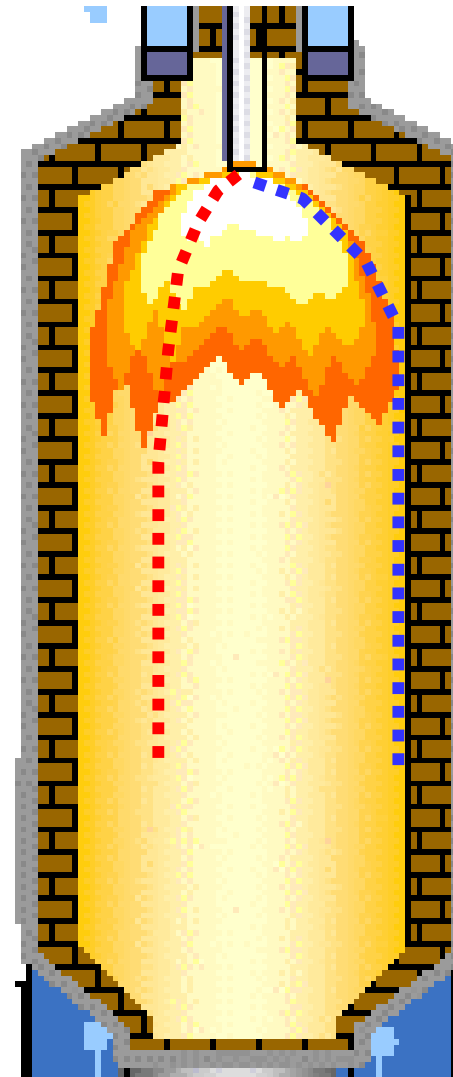
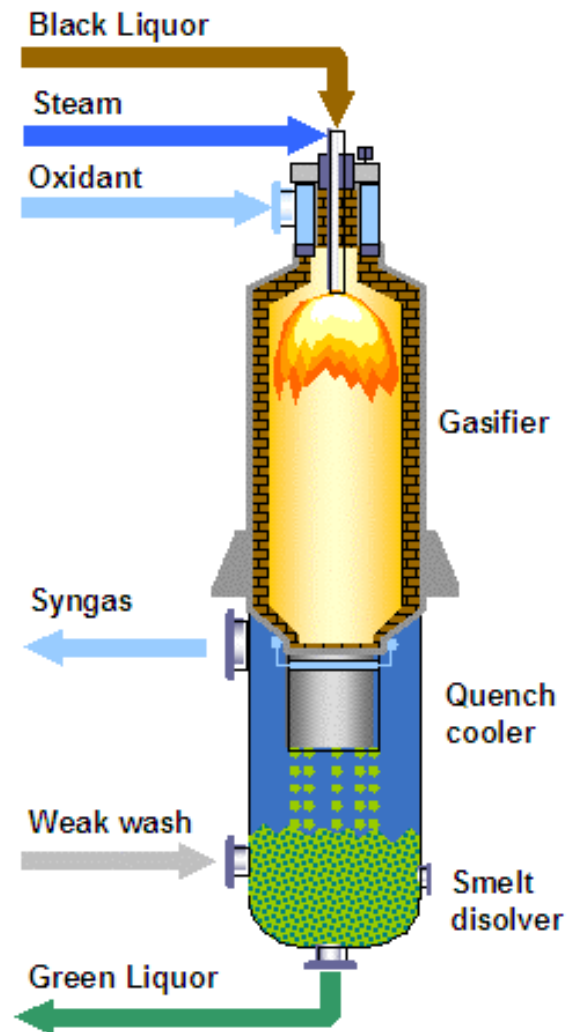


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- Pressurized, O₂-blown entrained-flow BL gasification offers great potential
 - Technology concept proven (New Bern, Skoghall)
 - Economic analyses favorable
- Additional R&D on gasifier performance needed
 - Knowledge thus far is primarily based on inputs and outputs ("black box")
 - Lack of information regarding what occurs within the gasifier
 - Data and submodels describing conversion and physical behavior under representative conditions are needed



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Pathways and Milestones – C-level and Project Milestones

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Ag Residues

Perennial Grasses

Woody Crops

Pulp and Paper

Forest Products

Validate performance of
gasification of spent
pulping liquor

M 6.1.1

Project Milestones	Type	Performance Expectations	Due Date
Develop models to describe liquor conversion specifics	D	Models will improve accuracy of computational fluid dynamic models used for design, optimization and troubleshooting of black liquor gasifiers	Sept. 2007
Evaluate injection and droplet formation in a hot environment	D	New and relevant data on liquor droplet injection will improve computational models describing such, and will improve general understanding of liquor feed behavior	March 2007
Measure smelt properties as function of temp and carbon content	D	Will improve accuracy of CFD models used for design, optimization and troubleshooting of black liquor gasifiers	June 2007



Pathways and Milestones – C-level and Project Milestones

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Ag Residues

Perennial Grasses

Woody Crops

Pulp and Paper

Forest Products

Validate gas cleanup
technologies for spent
pulpig liquor syngas

M 6.2.2

Verify fuel gas quality to
levels necessary for CHP
or clean cold gas
consuming equipment

M 6.5.1

Project Milestones	Type	Performance Expectations	Due Date
Characterize PHTBLG syngas, including minor species	D	Provide new and relevant data on PHTBLG syngas properties, particularly minor species, which intelligent design of syngas cleanup and utilization requires.	June 2007



Technical Feasibility and Risks

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- Basic technical feasibility of black liquor gasification proven
 - Good carbon conversion
 - Good recovery of pulping chemicals
- Utah program involves small-scale testing and lab experiments, presenting little risk



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- Provides data important for design of demo
 - Increased understanding of conversion fundamentals, syngas quality
 - Development of submodels suitable for incorporation into CFD models that can be used for design, optimization and troubleshooting
- Improves industry comfort level with technology
 - Runability under industrially relevant environment
 - More thorough knowledge of process details



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- Objectives
 - Acquire data on liquor injection, conversion behavior and syngas quality under representative conditions
 - Develop tools useful for design, optimization and troubleshooting of entrained flow black liquor gasifiers
- Approach
 - Operation and analysis of a small scale gasifier operating under conditions similar to those of a full-scale system
 - Augment gasifier studies with specific, lab-scale investigations under well-controlled conditions
 - Use the collected data to develop models to describe the observed behavior



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1. Construction of small scale entrained flow gasifier
2. Evaluation of black liquor injection
 - Experiments with liquor in hot environment
 - Include droplet formation and droplet swelling
3. Analysis of liquor conversion behavior
 - Physical characteristics (particle size, morphology)
 - Chemical composition of both gas and condensed phase
4. Investigation of molten smelt characteristics
 - Viscosity, emissivity, thermal conductivity
5. Characterization of synthesis gas
 - Attention to minor species
 - Variation during process upsets



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- University of Utah
 - Construction and operation of gasifier
 - Liquor conversion studies and model development
 - Syngas characterization
 - Smelt viscosity
- Brigham Young University
 - Liquor injection behavior studies
 - Smelt radiative properties
- Simulent, Inc.
 - Computational droplet model development
- Praxair
- Collaboration with Chemrec, Weyerhaeuser



History and Accomplishments

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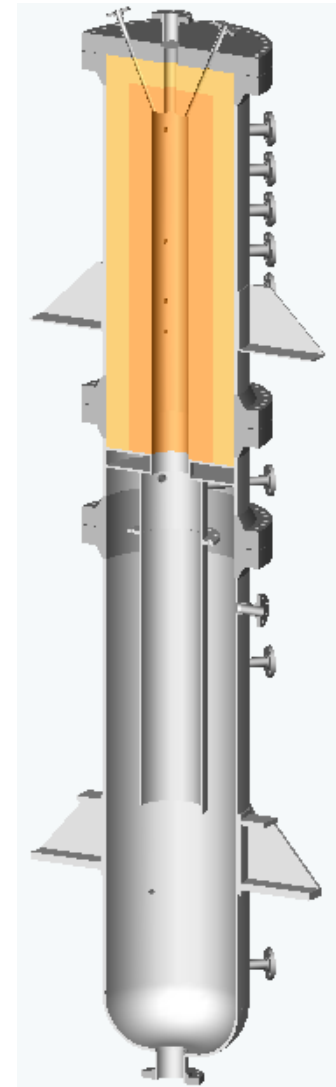
- Project is now in eighth month
- Accomplishments
 - Kickoff meeting, establishment of participant roles
 - Literature review
 - Gasification system design, procurement
 - Liquor injection test system design, construction
 - Smelt properties measurement system design
 - Five students hired



Accomplishments: Entrained-Flow Gasification Research System

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- Add to existing gasification research facility
- Reactor designed, ordered, being fabricated
- "Balance of plant" ordered





Accomplishments: Liquor Injection Studies

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- Heated optical chamber
 - Constructed
 - Heating successfully tested to 1000°C
- Liquor feed system
 - Components ordered and base system built
 - Successfully tested with water
- Imaging system available
 - Necessary optics procured





Accomplishments: Smelt Properties Analysis

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- Designed smelt properties measurement system
- Assessed viability of acquiring an available used slag viscometer. Chose not to pursue due to lack of tech support.
- Identified appropriate viscometer and design for measurement of molten smelt. In discussions with suppliers on design specifics.
- Device for thermal conductivity measurement in development.



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- FY 2005
 - Finish gasifier construction, shakedown
 - Finish droplet injection test apparatus construction
 - Finish construction of smelt properties measurement system
- FY 2006
 - Acquire data on droplet injection behavior
 - Acquire data on BL conversion
 - Acquire data on syngas properties
 - Acquire data on smelt properties
- FY 2007
 - Incorporate liquor injection data into computational model
 - Develop submodels to describe liquor conversion
 - Complete smelt properties measurements



Critical Issues and Show-stoppers

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- Performance requirements
 - Need to achieve steady-state operation of gasifier under pressurized conditions in oxygen-blown mode and associated sampling
 - Acquisition of data on liquor injection behavior and smelt properties under representative conditions
- Challenges
 - Burner performance
 - Refractory?
 - Sampling
- No show-stoppers



Plans and Resources for Next Stage

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- Next steps
 - Incorporation of data and submodels into design for pilot or demonstration system
 - Technical support of pilot/demo systems
- Commercialization partners
 - Gasification technology developers
 - Pulp and Paper companies
 - Industrial gas suppliers
 - Utilities
 - Fuel suppliers



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- Project progressing according to plan, on schedule and on budget
- Project supports several C-level milestones
 - Gasification performance
 - Fuel gas quality and associated cleanup
- Project addresses issues critical to understand of conversion in pressurized, high temp black liquor gasifiers
 - Greater understanding
 - Development of models
- Total funding (three year project):
 - \$780 K DOE
 - \$195 K Participants
 - \$975 K Total



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- Project Partners
- DOE/OBP
- Praxair
- Weyerhaeuser
- Chemrec
- Doug Singbeil, Paprican
- Jim Keiser, ORNL
- ICES